Growth and Yield 35 Years after Commercially Thinning 50-year-old Douglas-fir

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ABSTRACT

Remeasurement data over a period of 35 years from fourteen 0.2023-ha permanent plots were analysed to determine the growth and yield effects of commercially thinning 50-year-old Douglas-fir stands on a good site on Vancouver Island, British Columbia. Compared to unthinned stands, the commercially thinned stands had:

- virtually the same total volume gross annual growth, top height, and top height growth;
- 12% more potentially usable total volume yield (including thinnings);
- 18% less total volume at final harvest age 86;
- virtually the same crop-tree (193 largest-diameter trees per hectare) average diameter, but 24% larger entire-stand quadratic mean diameter; and
- 11% less total volume production lost to mortality.

These results show that commercial thinning slightly increased total stand yield (including thinnings) and produced larger stand diameter at rotation age 86, but that it also reduced usable total volume at final harvest and had virtually no effect on size of the crop-trees. Data from this study are useful for validating growth models, and for constructing and comparing managed stand yield tables for various commercial thinning regimes.

ACKNOWLEDGEMENTS

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INTRODUCTION

Commercial thinning can increase value and net revenue from forests by making some wood available early, and by producing larger trees at rotation. Thinning can also increase employment and overcome some wood supply problems. The potential magnitude of these benefits varies with the thinning regimes adopted, prevailing market conditions, and stand history. Although rarely practised in the past in British Columbia (mainly because of the abundance of old-growth forests and a lack of suitable second-growth stands), commercial thinning has recently become of great interest to forest managers, particularly in the 1940's plantations of coastal Douglas-fir.

Several studies of commercial thinning have been published in the Pacific Northwest (Worthington and Staebler 1961; Williamson 1966; Worthington 1966; Williamson and Price 1971; Reukema 1972; and Reukema and Pienaar 1973). There are also some informal reports of commercial thinning studies in coastal Douglas-fir in British Columbia.[1,2]

This report documents growth and yield following a moderate, double-entry commercial thinning in a 50-year-old coastal Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) stand on a good site in the CWHa2 variant (Klinka *et al.* 1984) on Vancouver Island, B.C. It is based on 35-year remeasurements and observations from B.C. Ministry of Forests and Lands Research Branch Experimental Project (EP) 364, the only well-designed and consistently remeasured and maintained long-term study of its kind in coastal British Columbia.

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1 Wright, T.G. 1986. Report on commercial thinning in a Douglas-fir stand. Unpubl. report on Tree Farm No. 1, Type 7. 2908 West 49th Avenue, Vancouver, B.C. 12 p.

2 Reid, D. and B. English. 1977. Comparison between thinned and unthinned stands 53 years old, 20 years after commercial thinning and pruning. Unpubl. rep. on Project 22-06-05, British Columbia Forest Products Ltd., Vancouver, B.C. 42 p. + Appendices.

METHODOLOGY

Study Area

Experimental Project 364 was established in 1950 in a Douglas-fir stand of age 50 years by the B.C. Forest Service. It is roughly 10 km from Cowichan Lake village on the east coast of Vancouver Island. The study was to determine growth response and potential utilization and profit from thinning immature Douglas-fir stands.[3] The study area was 20 ha of a fairly uniform, well-stocked 50-year-old stand of 90% Douglas-fir (by volume) and 10% western hemlock (*Tsuga heterophylla* [Ref.] Sarg.), western redcedar (*Thuja plicata* Donn.), and some hardwoods. The stand originated from natural regeneration following clearfelling of old growth in 1891, making it one of the oldest second-growth stands in the province. The ground is level and the soil type is a well-drained deep sandy loam. The Douglas-fir site index is estimated to range from 36 to 43 m (average 40 m) at 50 years breast-height age, based on Bruce's (1981) site curves. For further details on the characteristics of the study area, see Joergensen (1952, p. 1-2).

The climate near the study area is characterized by warm summers and mild winters. The annual precipitation is about 2123 mm (7% falls as snow), and the daily temperature average 9.1°C (with a minimum of - 1.5°C and a maximum of 24.1°C).

Study Design and Treatments

The original design consisted of seven thinned plots, and seven unthinned (control) plots. Three of the control plots, which are not included in this report, were clearfelled about 20 years after establishment.

To set up a practical commercial thinning operation, three separate blocks of areas 32.3, 5.3, and 12.3 acres (13.1, 2.1, 5.0 ha, respectively) were selected for thinning within the study site. Seven 0.5-acre (0.2023-ha) rectangular plots were established within these blocks. Also, seven plots of the same dimension and shape were established in similar, adjacent unthinned portions of the study stands (Figure 1). In general there was little variation in initial (before first thinning) stand characteristics between the stand designated for thinning and the unthinned stand, although the thinned stand averaged slightly fewer but larger stems, and 2% more basal area than the unthinned stand (Table 1). The average height to the lowest live branch was 26-36% of total height.

Layout of plots, marking of trees to be thinned, layout of roads and landings, and cruising of timber for sale were done in autumn 1950. Logging by horses was started in February 1951 and continued until February the following year. The thinned trees, bucked into 18-ft (5.5-m) logs, were all sold as sawlogs of unknown value and top diameter. The total volume extracted from the three blocks was about 134 200 ft^3 (3800 m^3). The average cost of logging was about \$5.15/m^3 (at a rate of \$2.00/hour). Logging damage was minimal, with stem scars about 1 ft^2 (.09 m^2) or less in area.

Thinnings were made at ages 51 and 69; the plots were measured at 5- to 7-year intervals between ages 51 and 86, including before each thinning (Table 2). The first thinning was moderately heavy and neutral, with d/D = 0.99. It removed an average of 44% of the original volume (Table 3). The thinning, although done in 1951, is still typical of commercial thinnings in British Columbia. It was done too late in the life of the stand to effect any growth response. The second thinning was light and low, with d/D = 0.75, and removed an average of 10% of the standing volume (Table 3). During the 35-year period, a total of 28 trees per hectare have been lost in the thinned plots and 3 in the unthinned plots through trespass cutting for road and recreation site access.

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[3] Joergensen, C. 1951. Commercial thinning - North Arm Forest. Working Plan, EP 364. B.C. Ministry Forests and Lands, Res. Branch File EP 364.

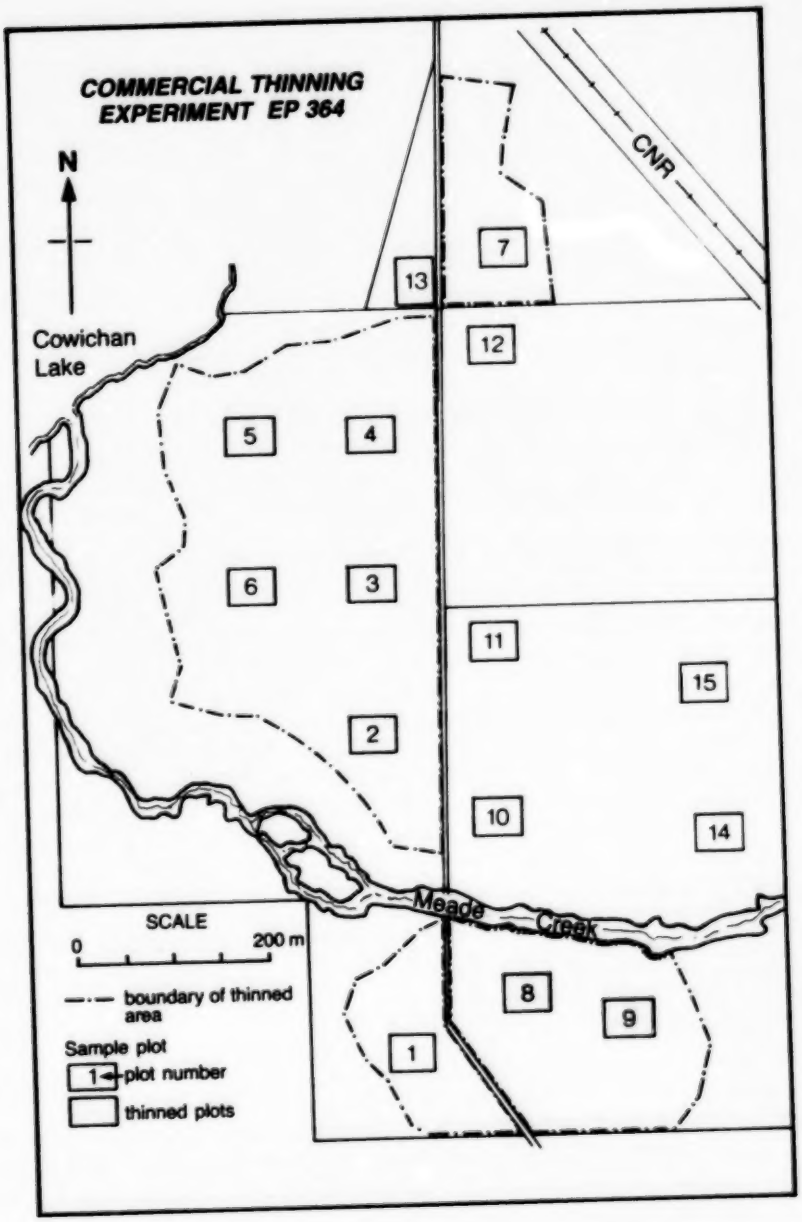

FIGURE 1. EP 364 study area and plot layout.

TABLE 1. Pre-treatment stand attributes

Attribute	Unthinned (4 surviving plots)	Thinned (7 plots)	Difference (% of unthinned)
Stem count (/ha)	1029	904	12
Basal area (m^2/ha)	51.5	52.5	2
Total volume (m^3/ha)	639.4	652.8	2
Top height (m)	35.4	35.8	1
Quad. diameter (cm)	25.2	27.2	8

TABLE 2. EP 364 plot remeasurement and treatment schedule

Measurement[a]			
Date (month/year)	Total age (yr)	Plot nos.[b]	Treatment[c]
8/1951	51	1-5, 7-15	• Initial thinning: plots 1-5, 7-9 (d/D = 0.99; average of 43% volume removed)[d]
5/1957	56	1-5, 7-15	
5/1963	62	1-5, 7-15	
5/1970	69	1-5, 7-15	• Second thinning: plots 1-5, 7-9 (d/D = .70; average of 10% volume removed)
5-6/1975	74	1-5, 7-9, 13-15	
7/1980	80	1-5, 7-9, 13-15	
10/1986	86	1-5, 7-9, 13-15	

[a] All plot trees were measured for diameter at breast height (4.5 ft; 1.37 m) outside bark; a subsample was measured for total height. Imperial measurements made prior to 1975 were converted to metric before analysis.

[b] Plots 10, 11, and 12 were clearfelled in 1970/71 to allow for the establishment of an arboretum and are not included in this report; plot 6 was measured separately as part of a natural regeneration study.

[c] There was severe wind and snow damage in the winter 1968.

[d] d = Quad. mean diameter at breast height of thinned trees.
D = Quad. mean diameter at breast height of entire stand before thinning.

TABLE 3. Attributes of trees removed in the thinnings

Attributes of removed trees	Thinning no.		Trespass cutting[a]	Total
	1 (age 51)	2 (age 69)		
Stem count (/ha)	430	78	28	536
Basal area (m^2/ha)	22.4	4.7	1.0	28.1
Total volume (m^3/ha)	280.3	60.2	12.0	352.5
Total height[b] (m)	30.9	26.3	-	-
Quad. diameter (cm)	26.8	27.7	-	-
d/D ratio[c]	0.99	0.75	-	-
% Volume removed	44	10	-	-

[a] In the unthinned plots, three trees per hectare (total volume = 6.8 m^3/ha; basal area = 1.0 m^2/ha) were lost to trespass cutting.
[b] Arithmetic average height.
[c] d = Quad. mean diameter at breast height of thinned trees.
D = Quad. mean diameter at breast height of entire stand before thinning.

Analysis

The analysis examined the effects on growth and yield of commercially thinning coastal Douglas-fir stands, based on the seven thinned plots and the four surviving unthinned plots. The economics of the thinning, the major original objectives of EP 364, have been briefly discussed by Joergensen (1951, 1952).

The following entire-stand and crop-tree average and per-hectare values were obtained from individual tree measurements for each plot and period of measurement: top height, quadratic mean dbh, stem count, basal area, and total and merchantable volume. Crop-tree summaries were obtained from 39 trees per 0.2023-ha plot (193 trees per hectare), the highest common number of residual trees in the plots, on the basis of the largest present (age 86) dbh, and then traced back through the remeasurement periods. Top height was calculated as the average height (measured or estimated from a height-diameter curve) of the 100 largest-diameter trees per hectare (as estimated by the 20 Douglas-fir trees per 0.2023-ha plot). Quadratic mean dbh is the diameter at breast height, outside bark, of a tree with plot mean basal area. Total volume is whole stem, inside bark, estimated from volume tables (B.C. Forest Service 1976; Omule *et al.* 1987). Merchantable volume is the total volume between a 30-cm stump and a 10-cm diameter inside bark top, estimated from the existing merchantable volume factors (B.C. Forest Service 1976; Omule *et al.* 1987).

Mortality

Per-hectare number of stems, basal area, and total volume lost to mortality during each remeasurement interval were acummulated to age 86 and plotted for the thinned and unthinned plots. As well, stem count per hectare and diameter distributions were plotted to illustrate the effects of thinning on stand development.

Growth and Yield

The analysis graphically compared standing yield, cumulative yield (including thinnings), and gross production to age 86. It also compared the gross growth of the thinned and unthinned stands over the 35-year period, on the basis of the usual stand attributes.

Adjusted treatment means were calculated from plot values for the entire-stand and crop-tree top height, basal area, and total and merchantable volume.[4] Adjusted quadratic mean dbh was calculated based on unadjusted mean stem count and adjusted mean basal area.

[4] Adjusted means, based on analysis of covariance and calculated using SAS (SAS Institute, Inc. 1985, p. 246-248), take into account the possible confounding effect of different initial stand values and site quality in the thinned and unthinned plots.

Standing yield (= adjusted means of live trees at age 86), cumulative yield (= standing yield + cumulative thinnings), and gross production (= cumulative yield + cumulative mortality over the 35-year period) were calculated in terms of basal area per hectare and total and merchantable volumes per hectare, and plotted for the thinned and unthinned stands.

Gross annual growth in quadratic mean dbh, top height, basal area, and total and merchantable volume was calculated by dividing the difference between the attribute's adjusted mean for standing trees at beginning of a growth period and the attribute's adjusted mean for all trees at end of the period, by the number of growing seasons in the growth period. These values were plotted for thinned and unthinned stands by measurement interval.

RESULTS AND DISCUSSION

Mortality

Generally, mortality in the thinned stands was much less than that in the unthinned. Over the 35-year period, the unthinned stands lost 519 trees per hectare (a total volume loss of 253 m^3/ha or 18% of gross production), whereas the thinned stands lost only 103 trees per hectare (91 m^3/ha, or 7% of gross production). That is, the total volume lost to mortality in the thinned stands was about 36% of the volume lost in the unthinned, suggesting that thinning salvaged impending mortality.

These results may be confounded by the substantial mortality from the 1968 snow damage, in which many more trees were lost in the unthinned than in the thinned stands. Compared to that of some unthinned Douglas-fir stands on Vancouver Island,[5] however, the development of the unthinned stands in this report appears to be progressing normally (Figure 2).

Tree mortality, especially in the period age 62-69 (in which snow damage occurred), was mainly confined to the smaller diameter trees, with only the occasional larger diameter trees being lost (due largely to root rot which was prevalent in the study area) (Figure 3).

Growth and Yield

The effects of commercial thinning on stand growth and yield are briefly discussed below. Readers interested primarily in the yield summaries can proceed directly to Table 4 and Figure 4.

Height

Top height was not affected by the commercial thinning. The adjusted average top height at age 86 in the thinned and unthinned stands was 51.6 m and 51.4 m, respectively. Over the 35-year period, top height growth was about the same in both types of stand — about 0.45 m/yr. The top height/age profiles from all the 14 study plots were similar in shape to those defined by Bruce's (1981) site curves (Figure 5).

Diameter

Attained stand diameter was higher in the thinned than in the unthinned stands. At age 86 the adjusted entire-stand quadratic mean dbh in the thinned and unthinned stands was 51.6 and 41.7 cm, respectively. However, the adjusted crop-tree quadratic mean dbh was virtually the same in the thinned and in the unthinned stands — 57.9 and 56.4 cm, respectively. Over the 35-year period, and excluding the 3.8-cm arithmetic increase due to trees cut in the thinnings (Figure 6), quadratic mean dbh in the thinned stands increased by about 25% more than in the unthinned (20.6 cm versus 16.5 cm). This 4.1-cm difference represents a combination of the actual growth of comparable trees in the thinned relative to the unthinned stand, slower growth on the many more small trees present in the unthinned stand (Figure 7), and the arithmetic increase due to loss of smaller-than-average trees to mortality.[6] Crop-tree quadratic mean dbh increased by 22.6 cm and 18.3 cm in the thinned and unthinned stands, respectively, over the same period.

Basal area

Thinnings reduced residual basal area to a minimum of 58% of that in the unthinned stand (Figure 8). Gross annual growth in the 6-year period immediately after the initial thinning was 15% lower in the thinned than in the unthinned stands. Since that time, however, gross growth has been about the same in both types of stand, even if the thinned stands have lower levels of growing stock (Figure 9.)

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[5] Based on data from permanent plots of Research Branch EP's 283 (Schenstrom plot), 365, and 499, which are on file at B.C. Ministry of Forests and Lands, Research Branch, Victoria, B.C.

[6] D.L. Reukema. Personal communication. 1987. Review comments on earlier draft of this report.

TABLE 4. A summary of attributes of standing trees at ages 51 and 86[a]

Attribute	Thinned stands		Unthinned stands	
	Age (yr)—51	86[b]	51	86
Entire stand				
Stem count (/ha)	474	265	1029	507
Average diameter[c] (cm)	28.4	51.6	25.2	41.7
Top height[d] (m)	35.8	51.6	35.4	51.4
Basal area (m^2/ha)	30.1	55.4	51.5	69.1
Total volume (m^3/ha)	372.5	926.6	639.4	1131.3
Crop trees[e]				
Average diameter (cm)	35.3	57.9	38.1	56.4
Average height[f] (m)	33.5	47.9	35.3	49.2
Basal area (m^2/ha)	18.9	50.9	22.0	48.2
Total volume (m^3/ha)	242.9	868.9	281.0	825.4
Merch. volume (m^3/ha)	230.1	840.6	268.0	800.1

[a] The age 86 summaries are adjusted means based on four plots for the unthinned stands and seven plots for the thinned; the values at age 51 are the unadjusted means *after* thinning.
[b] Total age from seed, as determined from stump ring counts.
[c] Quadratic mean diameter at breast height, outside bark of mean basal area tree.
[d] Top height = average height of 100 largest-diameter trees per hectare.
[e] Thirty-nine largest-diameter survivor trees per 0.2023-ha plot (or 193 trees per hectare).
[f] Arithmetic average height.

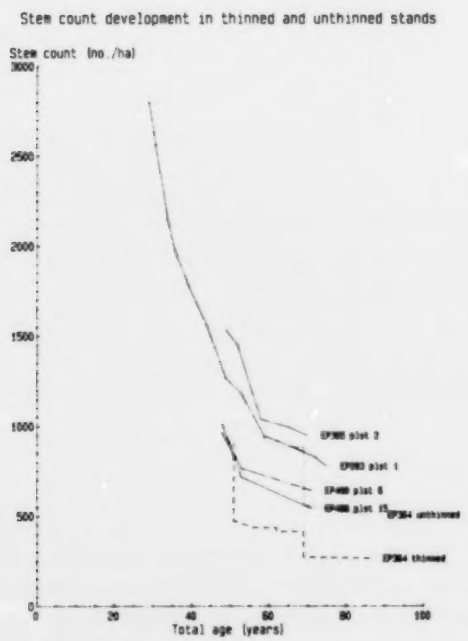


FIGURE 2. Stem count development of thinned and unthinned stands.

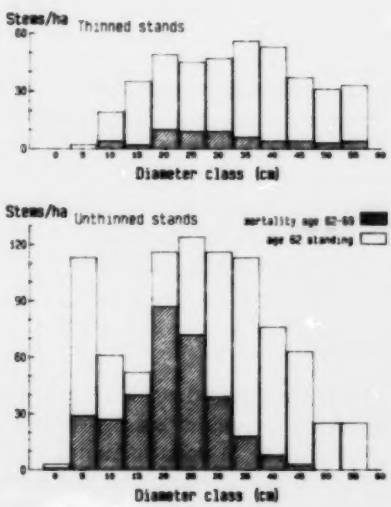


FIGURE 3. Diameter distribution of mortality in the age 62-69 period.

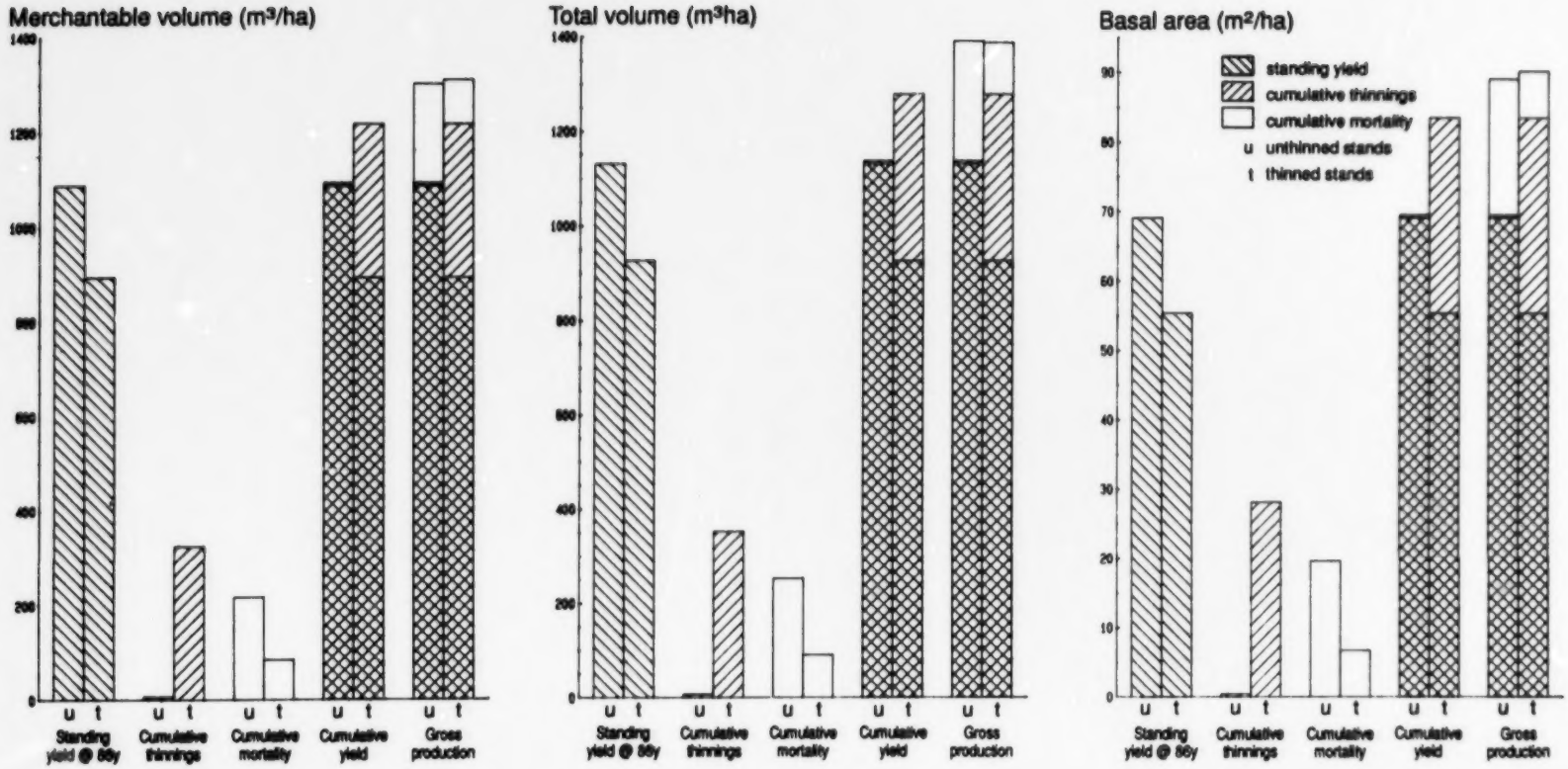


FIGURE 4. Cumulative thinnings, mortality, yield, and gross production of thinned and unthinned stands.

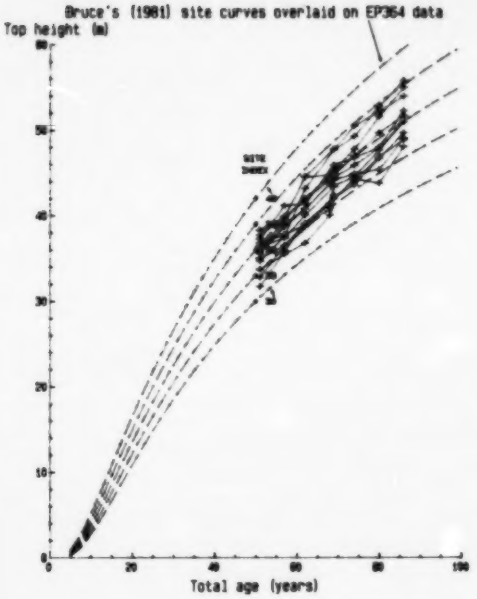


FIGURE 5. Top height/age profiles of EP 364 plots.

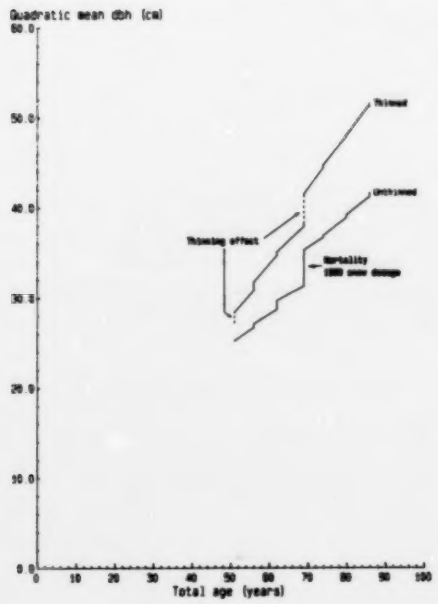
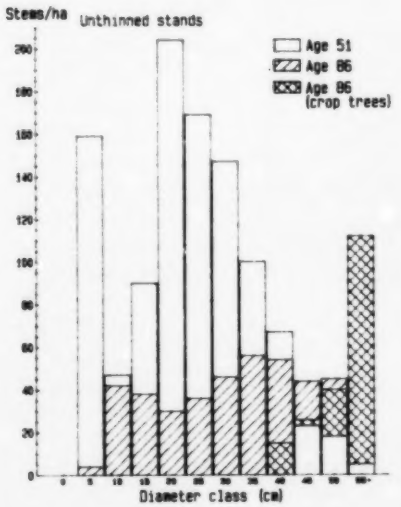


FIGURE 6. Stand diameter development of thinned and unthinned stands.



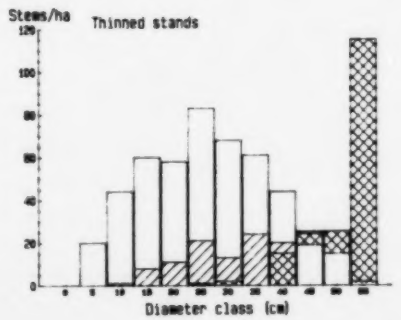


FIGURE 7. Average entire-stand and crop-tree diameter distributions after the age 51 thinning and at age 86.

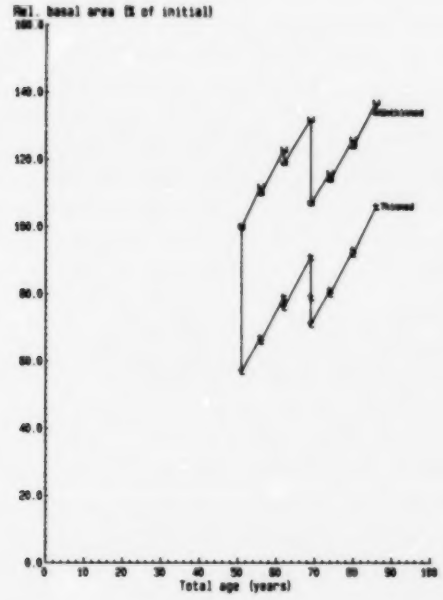


FIGURE 8. Relative basal area development of thinned and unthinned stands.

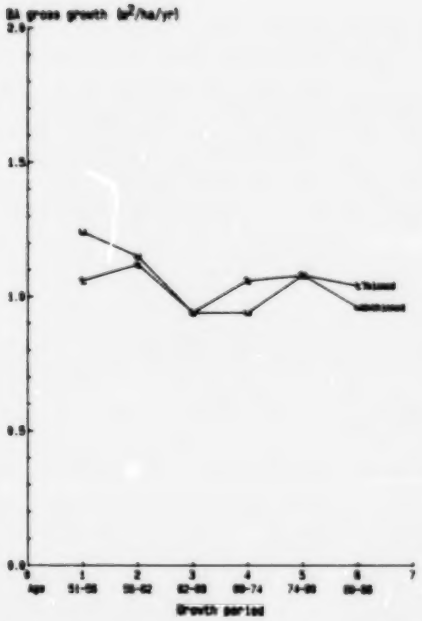


FIGURE 9. Periodic annual increment in basal area per hectare.

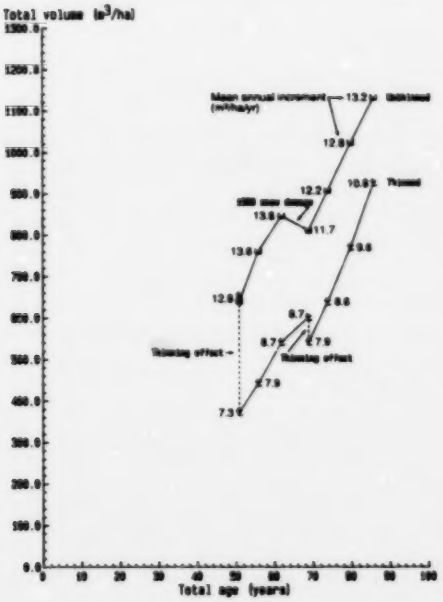


FIGURE 10. Curves showing total volume over age for thinned and unthinned stands.

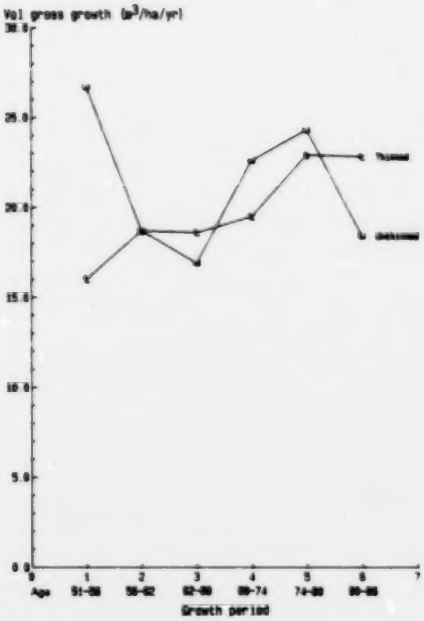


FIGURE 11. Periodic annual increment in total volume per hectare.

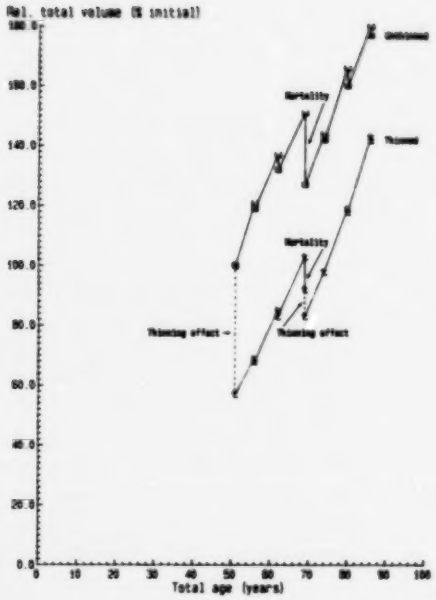


FIGURE 12. Relative total volume development of thinned and unthinned stands.

The adjusted basal area of standing trees at age 86, plus cumulative thinnings, was 83.5 and 69.5 m^2/ha in the thinned and unthinned stands, respectively. That is, the thinned stand produced about 14.0 m^2/ha (20%) more cumulative basal area yield to age 86 than did a comparable unthinned stand. This difference might be slightly exaggerated because of excessive irregular mortality in the unthinned plots during the 1968 snow damage. (It was not possible to separate regular and irregular mortality.)

At a final-harvest age of 86 years, the adjusted basal area available in the unthinned stands was higher than in the thinned stands by 13.7 m^2/ha (20%). The unthinned stands had a basal area of 69.1 m^2/ha at age 86. Gross production was only about 1% higher in the thinned than in the unthinned stands — about 90.2 and 89.1 m^2/ha, respectively (Figure 4). Thus, as expected, commercial thinning has provided an earlier harvest of part of the stand and recovered impending mortality, but reduced final harvest basal area.

Total volume

Total volume mean annual increment is lower in the thinned stand than in the unthinned, but neither stand has reached a maximum mean annual increment (Figure 10).

Gross annual growth in the 6-year period immediately after the initial thinning was about 40% lower in the thinned than in the unthinned stands. Since that time, however, the growth has been about the same in both types of stand (Figure 11), even if the thinned stand has lower levels of growing stock (Figure 12).

The adjusted total volume of standing trees at age 86, plus cumulative thinnings, was 1279.1 and 1138.1 m^3/ha in the thinned and unthinned stands, respectively. That is, the thinned stands produced 141.0 m^3/ha or 12% more cumulative total volume yield to age 86 than did comparable unthinned stands.

The adjusted total volume available for harvest at age 86 was higher in the unthinned than in the thinned stands by 204.7 m^3/ha (18%). The total volume available for harvest in the unthinned stands at age 86 was 1131.3 m^3/ha. Based on crop trees, however, the total volume available for harvest was higher by 5% in the thinned than in the unthinned stands. Gross production to age 86 was less than 1% different in the thinned and unthinned stands — 1387.7 and1390.9 m^3/ha, respectively (Figure 4).

Merchantable volume

The results for merchantable volume, the total volume between a 30-cm high stump and a 10-cm diameter inside bark top, were virtually the same as those for total volume. The adjusted merchantable volume of standing trees (including cumulative thinnings) at age 86, was 1218.7 and 1094.3 m^3/ha in thinned and unthinned stands, respectively. That is, the thinned stand produced 124.4 m^3/ha or 11% more cumulative merchantable volume yield to age 86 than the unthinned stand. The adjusted merchantable volume available for harvest at age 86 was 17.8% higher (194.0 m^3/ha) in the unthinned than in the thinned stand. The unthinned merchantable volume at harvest was 1087.8 m^3/ha, 92% of which resided in trees with dbh greater than or equal to 42.5 cm (compared to 97% for the thinned stands). Note that the merchantable volume results may change depending on how "merchantable volume" is defined in terms of the stump height and top diameter limits.

CONCLUSIONS

For the range of site, stand, and treatment conditions in this study, the results indicate that:

- The thinned and unthinned stands had virtually the same total volume gross annual growth.
- The thinned stands produced 12% more potentially usuable cumulative total volume yield (including thinnings) to age 86 than did the unthinned stands.
- At a rotation age of 86 years, the unthinned stands had 18% more total volume available for final harvest than did the thinned stands.
- Crop-tree diameter was about the same in the thinned and unthinned stands at age 86; however, the entire-stand diameter was 24% larger in the thinned than in the unthinned stands.
- Top height and top height growth were about the same in the thinned and unthinned stands.
- The top height/age profiles of the stands studied were similar in shape to Bruce's (1981) site curves.
- There were no important differences in gross production between the thinned and unthinned stands.
- The gross production (total volume) lost to mortality was 7% in the thinned stands, and 18% in the unthinned stands.

This study supports previous research which shows that commercial thinning of coastal Douglas-fir results in: marginally more cumulative volume yield over the rotation; and fewer and larger trees at final harvest, but also lower total volume (Worthington and Staebler 1961; Reukema and Pienaar 1973; Reukema and Bruce 1977). The importance of these effects, and whether to thin or not, will depend upon several other factors, such as the economics of the commercial thinning (frequency, grade and timing) and stand history and conditions, as well as the need to create employment and alleviate local timber supply problems. The growth and yield data collected and the actual growth response values obtained to date are useful for validating growth models such as TASS (Mitchell 1975), and for constructing and comparing managed stand yield tables for various commercial thinning regimes.

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